Full-Cost Approach to Airport Pavement Management

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Abstract

Airport pavements are a key element of the commercial airport infrastructure that often are taken for granted. The current Federal Aviation Administration (FAA) endorsed pavement management system developed in the 1970's does not meet the needs of U. S. commercial service airports because it ignores all modes of pavement failure other than surface distress. Not only is it a time consuming and costly system to apply, but it also fails to meet the commercial needs of airline and airport users: costs of user delays from closed runways and taxiways are ignored, as is the reduction in aircraft service life due to increased fatigue from operating on rough runways. Commercial service airports need an enhanced pavement management system (EPMS) incorporating full cost evaluation. An appropriate pavement management system should address the full economic impact of pavement work, including disruption costs and aircraft operational costs. Recent advances in geographical information systems (GIS) make it the best framework for integrating an enhanced airport pavement management system. An integrated airport GIS has the capability to calculate full costs as a function of pavement location.

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Introduction

Our national aviation system faces growing constraints on airport capacity and increasing costs to the users through airport delays. Growth in passenger traffic is expected to double within seventeen years, yet construction of new airports will not keep pace with demand. The financial burdens on the US airline industry since deregulation have been well documented. In 1993, nearly every US airline lost money. Airport expansion and modernization under the federally funded airport improvement program (AIP) for airport construction has decreased for the last two years, even though contributions to the Aviation Trust Fund have increased.

Airlines are making schedule and hubbing decisions based upon demand, market shares and cost per enplaned passenger at the airport. Consequently, airports are competing among themselves to provide better service at lower cost to the airlines, hence the traveling public. One way of increasing efficiency at airports is to improve engineering, management and decision making by doing a better job of managing information and data. The development of a multiple user, multiple application GIS is one way to reduce costs and improve airport efficiency with scheduled airline traffic. A pavement management system (PMS) should be one of the applications within such an integrated airport GIS.

Congressional Pavement Maintenance Management Initiatives

Public Law 103-305 requires that after January 1, 1995, airports requesting AIP funds for pavement replacement or reconstruction must have an effective pavement maintenance management system in operation. On the surface, this seems to be a wonderful idea, especially for consultants anxious for airport development projects. The Federal Highway Administration (FHWA), under the recent Intermodal Surface Transportation Efficiency Act (ISTEA), also has required each state highway department to maintain a pavement management system. However, FHWA and the National Cooperative Highway Research Program (NCHRP) have been supporters of pavement management research for over 20 years and the industry only now is developing a stable and usable product for state highway agencies.

In the case of the FAA, pavements have been largely ignored, except where construction funding is concerned. Although the FAA spends nearly $2 billion in airport pavement construction each year, it only spends $2 million annually on airport pavement research. Although a recent $30-million research program has been proposed, its focus is primarily to support the B-777 and other new large aircraft. The FAA has relied heavily on the leadership, research and technical support of the military. Without the support of the Waterways Experiment Station and the Air Force Engineering Support Agency, the FAA would have almost no technical expertise in airport pavements, except for design procedures and construction specifications.

Airport pavement management systems began with research conducted in the 1970’s by the Construction Engineering Research Laboratory (CERL) for the US Air Force under the direction of what is now the Air Force Civil Engineering Support Agency (CEEDO, 1977). This research led to the development of the PAVER and MicroPAVER pavement management systems.

The purpose of PAVER was to develop an airport pavements rating system so that a substantial pavement maintenance budget could be prioritized to serve those bases that needed it most. In the military, new construction (or reconstruction) generally is not an option since it requires congressional approval, which often takes several years. For example, during the 1970’s officials at Laughlin AFB, TX were surprised to receive money that had been requested approximately seven years earlier, when Laughlin was a Strategic Air Command base, to reconstruct a major taxiway. Even though by the time the funding came through, the base had become a Air Training Command base (flying only light trainer aircraft) the taxiway was redesigned for the lighter aircraft and reconstructed with the new-found funds.

The salient point is that the U. S. Air Force, by necessity, spends far more maintenance dollars on airport pavements per base than nearly all commercial service airports. The rating system of the PAVER system actually was developed by taking many experienced U. S. Air Force pavement maintenance engineers and quantifying their collective best guesses about the relative damage each type of distress causes pavement systems.

The FAA has adopted the methodology of the Pavement Condition Index (PCI) developed for PAVER and encourages airports to use the pavement condition index for airport surveys (FAA, 1982). The PCI is a visual grading system that collects data on the amount and severity of all distresses observed on pavements and computes a quantified index of distress which has repeatable results. The FAA will share the cost of a pavement condition survey for master planning and for scoping under the airport improvement program (AIP) for the initial design of a rehabilitation project.

The FAA does not and probably never will provide funds for routine airport maintenance. For many years, neither did the FHWA. This despite the fact that is common knowledge that every dollar spent on maintenance saves three or more in reconstruction costs later. The FHWA now does provide federal contributions to state maintenance activities.

Many airports, especially the smaller general aviation facilities which do not receive sufficient landing fees to cover operations, have no pavement maintenance program to speak of. At those airports, nothing is done until a reconstruction or treatment is required that is worthy of an application for funds with a matching federal contribution.

The goal of the congressional mandate that airports implement a pavement maintenance management system to receive AIP funds is to eliminate the practice of ignoring maintenance and requesting federal funds for reconstruction. However, the FAA's interpretations and implementations of this mandate will be critical to the airline industry and the national airport system. If the FAA interprets this mandate to mean that every airport should develop a pavement management system (such as their endorsed MicroPAVER) and that airports must conduct annual pavement condition surveys, airports will be forced to comply with an unfunded and unnecessary requirement costing hundreds of million of dollars for very little gain in return.

Guidance from the FAA about what constitutes an effective pavement maintenance management system is expected in late 1995. Early indications from the FAA are that airports will be subject to minimal requirements regarding pavement inspections and record keeping. This is due to the fact that the new standards will include general aviation airports, which cannot afford additional expenses. Although annual collection of distress data could be beneficial, the expense of PCI data collection in accordance with ASTM procedures would be less than cost effective. Airports should avoid falling into a trap of implementing an annual PCI data collection program just because the FAA endorses it.

Limitations of the Micro PAVER Pavement Management System

MicroPAVER is the personal computer version of the main frame PAVER developed for the U. S. Air Force. MicroPAVER has been endorsed by the Air Force, the FAA and APWA for roads and streets. The current version (3.0) is expected to be superseded by a new Windows Version 4.0 in late 1995. Many previous limitations related to data transfer and database connections will be eliminated. Unfortunately, the analysis routines and the data collection constraints will not be.

The MicroPAVER system is inadequate as a pavement management system for several reasons including the following:

- Pavement life is based solely upon prediction of declining PCI.
- All modes of failure other than surface distress are ignored in pavement analyses.
- It cannot be used as the sole basis for decision making on reconstruction, maintenance or construction.
- It does not address the indirect costs and concerns of high-use commercial service airports.
- The PCI requires too many man-hours for data collection.
- The version 3 software does not allow data exchange or modification of the analysis routines. (Data exchange problems will be corrected in version 4.)

Despite the millions of dollars spent by the Air Force and the FAA on MicroPAVER, it has not been well received by engineers in the field, either at airports or air force bases. Although the Data Structure of PAVER has become a standard for airport pavements, MicroPAVER is little more than a database for storage or PCI calculations.

Economic Evaluation of Pavements

Cost benefit analyses have been used in highway evaluation for more than four decades, essentially stimulated by data reported in the AASHO Red Book (AASHO, 1952). A more comprehensive treatment of user costs then followed, focusing on vehicle operating costs or VOCs, which in the U. S. were principally reported by Winfrey (Winfrey, 1969) and Claffey (Claffey, 1971).

In the 1970's, economic evaluations of pavement rehabilitation strategies generally concentrated on minimizing agency costs, but the few that did include user costs concentrated on fuel and time elements. This was relatively straightforward, since estimates of speed had to be made to determine fuel consumption and speed differentials then gave rise to driver and passenger delay costs.

Planners modeling these costs found that the elements were surprisingly large. For example, when developing work zone models in the mid 1970's, researchers found that delay costs alone overwhelmed the agency costs associated with pavement reconstruction and rehabilitation (Butler, 1973). This was reflected in results from World Bank work in Brazil, based on a system developed at the Massachusetts Institute of Technology (MIT) (Moavenzadeh, 1971). Ultimately, it led to the widely used Highway design and Maintenance Model - HDM III (Watanatada, 1988), which showed that over a 20-year period, user costs represented more than 85% of total discounted project costs. The development of economic analyses in general highway evaluations led to their incorporation into the growing number of PMS models developed during the same time period.

In all the highway evaluation models so developed, be they pavement, work zone, rehabilitation or construction, by the 1980's it was generally recognized that some kind of economic life cycle treatment was desirable. Within this approach, all activities in the full life cycle of the facility are identified, costed and then discounted back to provide a variety of economic indicators. From a pure economic perspective, the development of net present value was the most reliable indicator, but typically life cycle cost analyses were developed so they could report a variety of indicators, including cost benefit ratios, net present value, internal rate of return, break-even analysis and first-year rate of returns. The latter was an indicator of the impact of the project, and planners generally reviewed the array of indicators prior to choosing specific strategies.

However, it remains true that if an agency is facing a capacity constraint with respect to the supply of investment funds, it needs to make the assessment on the basis of net present value to ensure true economic efficiency. This is where we stand with most of the highway PMS approaches. We have life cycle cost with a traditional treatment of agency and user costs giving a variety of economic indicators. This is of interest to airport planners, since the PMS approaches suggested for airport use are typically based on methods derived from highway development over the last 15 years.

However, there are now new developments with respect to the treatment of these costs that should enhance PMS applications for airport use. It is clear that using only agency and user costs will miss a number of key cost inputs. Traditionally, when costs that attend specific construction activities are not included in the evaluation, they have been called externalities. Two key externalities appropriate to airport operations are noise and air quality.

Furthermore, it becomes apparent that a dedicated airport PMS model should split delay costs into those associated with aircraft operations and those associated with passenger time.

Figure 1 shows the input modules and outputs from a dedicated airport PMS model. The input modules comprise the pavement elements of the airport system and include the impact of construction activities on airport operations. These operations could range from gate delays and slot management, and include other costs such as additional labor required to handle planes arriving after the time allotted to their slots. These costs need to be expressed in dollars based on a 24-hour cycle, which can then be applied to the construction/rehabilitation cycle associated with the particular construction activity. While the construction is underway, any increase in aircraft costs, particularly associated with fuel, also needs to be calculated, and from these aircraft delays we would calculate passenger time delays. Ideally, passengers would be broken down into an appropriate business/social mix to arrive at different hourly rates for passenger time.

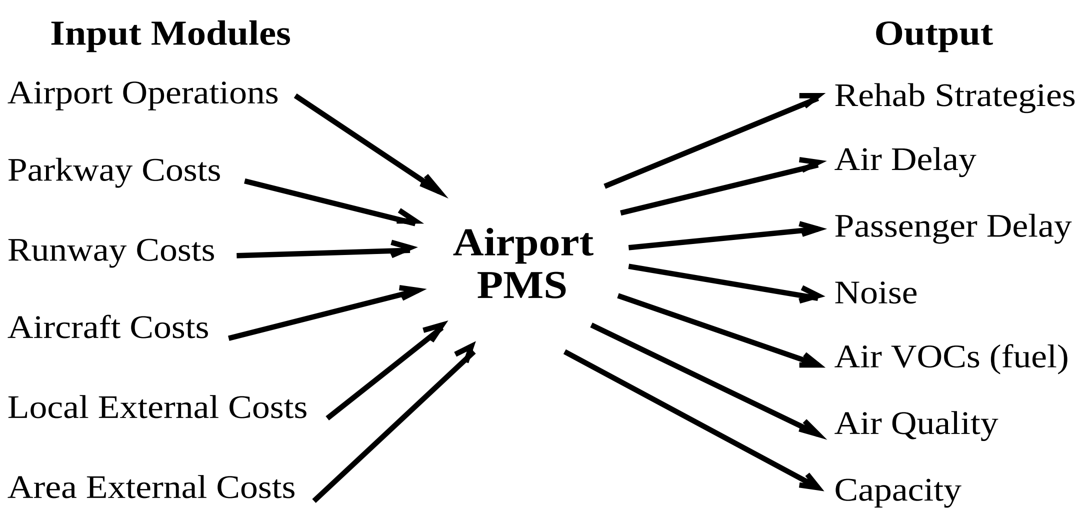

Figure 1. Inputs and Outputs of a Full-Cost Airport PMS

Costs included in the local externalities would be the noise associated with taxiing and waiting, plus air quality pollution. Area externalities could include pollution from increased holding patterns around airports with restricted runway availability. These would feed into the economic evaluation within the model and then would provide a series of outputs. The key output would be the rehabilitation strategy associated with the engineering problem. This would be based on attempting to minimize total costs, but these costs would comprise a wider range of categories than is currently used in economic analysis. They would be disaggregated and reported so that planners could see delays associated with aircraft and associated passenger costs, levels of noise, air quality associated with holding patterns, increased fuel costs from queuing for take-off and landing slots, and capacity impacts at the airport.

It is likely that a full cost analysis will result in strategies for airport pavement design that stress high initial quality and a long service life. This is because disruption to aircraft use is heavily penalized and measures to mitigate interruptions in service are therefore encouraged. Hand-in-hand with high quality designs are routines to regularly monitor pavement condition and sub-pavement strength for the early detection and correction of deficiencies before they become serious problems requiring lengthy and disruptive reconstruction.

Indirect Costs Related to the Management of Pavements

Other costs influence maintenance and reconstruction decisions. These include the cost of operating aircraft on the runways and taxiways, and delay costs when those taxiways or runways are not available.

Delay Costs

Everyone understands the value of keeping the busier air carrier runways open, but rarely is it quantified, either in terms of dollars or in terms of maintenance, repair or rehabilitation strategies. At Dallas/Fort Worth International Airport the Air Transport Association (ATA)estimated the cost of closing runway 18R/36L in 1990 at $131,000 per day in bad weather and $110,000 per day in good weather, based upon the delay to the airlines. This estimate was used to compare block paving construction of taxiways versus conventional construction. DFW engineers estimated that $4.3 million in potential delay costs were avoided by choosing construction with concrete block pavers, which allowed the runway to be open an additional 2 hours daily for 114 days (Lary, 1991).

The point is, that closing certain taxiways and runways affects the delay times of air carrier operators. The cost of delays changes annually and varies with the time of day and the location on the runway. Most importantly the costs are affected significantly by additional closures. Engineers work to minimize runway closure times by planning, using fast-track scheduling and innovative quick setting materials. It is possible calculate or estimate to potential delay costs and use those numbers in developing rehabilitation and maintenance strategies.

Other Delay Costs

For airlines, the costs resulting from runway closure delays do not end with increased operating expenses. They must factor in the cost of passengers time lost, the additional noise created by long delays during taxi, and the extra fuel burned that further degrades air quality. We estimate that an extra 5 minutes of taxi time will increase jet aircraft emissions enough to more than compensate for any savings expected from the conversion of aircraft ground support vehicles to zero emission fuels (as has been directed by the Environmental Protection Agency at Los Angeles International Airport).

Aircraft Fatigue Due to Rough Pavements

One often overlooked problem in the management of airport pavements is their roughness profile. In cases where the runway is particularly rough it can accelerate aircraft fatigue from both the dynamic response of the aircraft as well as accelerated loading on the pavement. Following several years' study, the U. S. Air Force has established roughness criteria for fighter aircraft in combat operations. On highways, pavement performance is generally accepted as the time history of change in profile roughness as measured by the present serviceability index (PSI). Better performance is achieved by maintaining better PSI for longer periods of time.

According to FAA policy, the runway is acceptable as long as it is constructed within the limit of 1/4-inch deviation from a 16-foot straightedge. However, the real concern should be the long wavelength deviations that induce loads to the aircraft. Computer simulations, previously verified by U. S. Air Force flight tests, show that some of our nation's air carrier runways are much more damaging to the aircraft than what is normally expected and design for aircraft service life. According to officials at

Boeing Aircraft Co., the effects of fatigue on an aircraft are exponential, as shown in figure 2. A vertical acceleration of 0.55 Gs is 1,000 times more damaging than the design acceleration of 0.35 Gs for take-off and landing (Gervais, 1991).

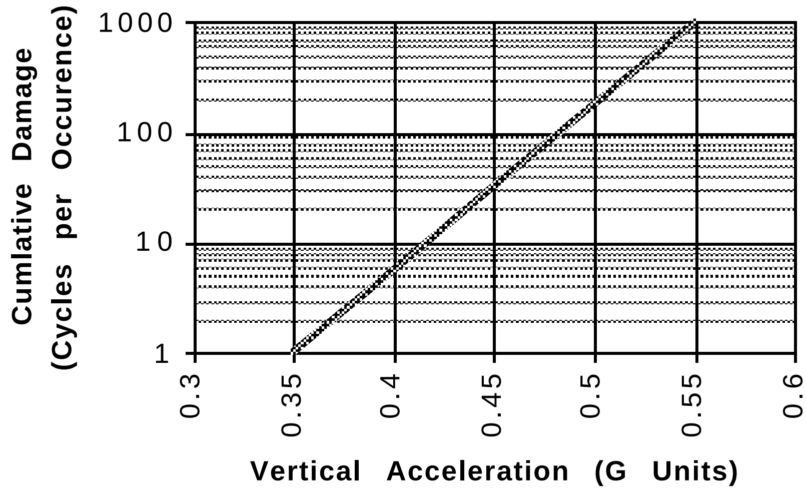

Figure 2. Effect of Runway Roughness Accelerations on Aircraft Fatigue

At some U. S. airports, the runway profile is rough enough to cause more than 1,000 times the fatigue damage of normal take-off or landing operations. This unnecessary fatigue damage to the nation’s air carrier fleet has largely been ignored because the tools to evaluate it properly have not been applied. While the FAA has begun a three-year study of the problem, it deserves more research and attention.

Airport Choice of Pavement Management Systems

Today, airport authorities have a choice of pavement management systems. Table 1 gives a comparison of what is included or required in some of the implementation options in pavement management systems. The FAA requirements, shown in column two, are minimal. The only FAA requirements are promulgated for minimum standards at general aviation airports, requesting them to consider inspections of their pavements, perform some maintenance and keep a records. Obviously, this is not enough for air carrier airports. Essentially, the MicroPAVER

Table 1. Comparison of Pavement Management System, Inputs and Requirements.

	FAA Pavement Maintenance Management Requirement	MicroPAVER	Traditional Highway Pavement Management System	Full-Cost Airport Pavement Management System
Pavement Inventory	YES	YES	YES	YES
Pavement Location	YES	YES	YES	YES
Pavement Maintenance History	YES	YES	YES	YES
Pavement Surface Inspection	YES	YES	OPTIONAL	YES
Pavement Condition Index (PCI)		YES		YES
Structural Capacity		OPTIONAL	YES	YES
Non-Destructive Testing (FWD)			YES	YES
Core Samples				YES
Subsurface Material Characterization			YES	YES
Surface Profile (Roughness)			YES	YES
Ride Quality		OPTIONAL	YES	YES
Transverse Profile (Rutting)			YES	
Skid Resistance		OPTIONAL	YES	YES
Rehabilitation Recommendations		YES	YES	YES
Aircraft Delay Time				YES
Passenger Delay Time				OPTIONAL
Aircraft/Vehicle User Costs - (Fatigue Damage)				YES
Noise Contributions				OPTIONAL
Air Quality Contributions				OPTIONAL
Capacity Issues				YES
Life Cycle Costs			YES	YES
Aircraft/Vehicle Traffic Data		OPTIONAL	YES	YES

system is a distress management system. It does allow the collection of data for structural capacity, ride quality, skid resistance and aircraft traffic data, but mostly, these data are ignored in the analysis routines and rehabilitation recommendations. The majority of the more successful large airport pavement management systems build upon and go beyond the MicroPAVER system. Traditional highway PMSs consider many more variables and primarily measure performance as maintaining ride quality for a variety of load applications.

A full-cost airport PMS requires more detailed analysis of fewer pavements than the traditional highway PMS. The complete economic costs of air carrier pavements are a controlling factor in how the pavements should be maintained, repaired or rehabilitated. Therefore, a full-cost approach to PMS should be used for managing this important asset.

GIS in Airport Pavement Management

In many airports, the capacity problem related to the number of operations per runway is a major issue that makes it both costly and difficult to close runways for maintenance. One advantage of GIS in airport pavement management is its capability to reduce the direct and indirect costs associated with work on airport pavements.

A documented example of the value of GIS for airport pavement management comes from the New York and New Jersey Port Authority. The consultant, which the port authority hired to develop the pavement management system for three airports (JFK, La Guardia, and Newark) used GIS very effectively for graphic display of pavement condition data (Schwartz, 1991). The key to proper pavement management ismaking the correct analysis of the data. To understand a problem as it relates to a runway, it is essential to see the effects and visualize the relationships. GIS is excellent for integrating mountains of tabular data, displaying it with geographical relationships and answering engineers' and decision makers' queries. A GIS also facilitates the interaction of environmental or traffic data with pavement data for a more complete analysis.

The next step in pavement management is to prioritize resources and pavement rehabilitation strategies. A pavement management system usually is designed to optimize pavement performance or pavement life. For airports, the optimization routines might be slightly different to make the best possible use of runway time. Regardless of the optimization strategy, the result must be measurable. What better way to compare the results of the potential budgets for alternatives than to have a visual display of the effects of comparative forecasts? GIS can be both an analysis tool for pavement management and a management tool for administrators.

Pavement management systems have not been very popular or effective at airports because the FAA-endorsed MicroPAVER program neither provides immediate cost/benefit gains above the painstaking data collection process and the work required to operate the software, nor does it keep up with current technology. And while the pavement condition index developed for airports in the 1970s does an adequate job of quantifying the distresses observed on the pavement surface, new technology now exists for ground penetrating radar (GPR), falling weight deflectometer (FWD) and spectral analysis of surface waves (SASW), which goes beyond what can be observed on the surface. Additional developments in the imaging of pavements and the analysis of surface roughness have great potential for analysis and prediction of pavement performance.

Graphic presentation of data helps managers to understand, analyze and then present results for complex airport pavement systems. A GIS can perform necessary functions such as integrating multiple databases on numerous platforms. The best common location reference system would be geographical. The Differential Global Positioning System (D-GPS), which is being implemented at airports for precision approaches, can supply the accuracy needed to locate any collected data (roughness, distress or NDT) in real time to an accuracy less than250mm.

Specifications for Airport GIS for Pavement Management

One of the important features of a GIS is its capabilities for graphic display of the PCI level and the locations of different types of distresses. While certain areas of the airfield may be developing slippage cracking, other areas may be experiencing rutting. The GIS can perform advanced spatial analyses to determine whether certain distresses are more prevalent in areas with older pavement, heavier traffic or poor drainage. Since more than 120 variables affect the life of a pavement, this could be a useful tool for pavement management. Clearly, the analyses of pavement life and performance is rarely straightforward, rather it is a study of multiple variables and, most importantly, the variable interactions.

A GIS-developed pavement management system is preferable to traditional systems in its ability to demonstrate the full costs as a function of the pavement location.

The locations of taxiways and runways affect potential aircraft delays. High traffic areas and bottleneck taxiways with a direct impact on aircraft delays deserve more costly but efficient repairs in order for service to be restored with a minimum of down time.

Specifications for Airport GIS for Pavement Management

1. The pavement database must be compatible structurally with that of MicroPAVER, and have, as a minimum, the same fields, field lengths and data characteristics.
2. The database must provide the capability to collect all distress data for the pavement condition index, and the software must computer the PCI for each section. The system must be capable of identifying which sections have similar types of distresses.
3. The system must provide a means for collecting and analyzing other pavement data not required in MicroPAVER, including international roughness index, modulus of elasticity for four layers and the coefficient of friction.
4. The airport GIS should permit traffic and environmental data collection for potential spatial analysis related to pavement performance.
5. Pavement sections are to be georeferenced to a horizontal accuracy of 1 to 3 meters. The system should provide section locations in the appropriate coordinate reference systems, including any local reference systems or map grid coordinate systems required for emergency response.
6. Horizontal accuracy requirements vary based upon the specific applications and analyses to be performed. If differential GPS positioning is planned for the airport, pavement sections within the aircraft movement area should be georeferenced with a horizontal accuracy of300mm.
7. In the background of the vector-based map, the system will be capable of displaying additional images such as scanned aerial photographs and digital orthophotography.
8. It should be compatible with existing relational databases and CAD drawings used by the airport.
9. Topological features must be developed for runway, taxiway and apron features so that spatial analysis can be performed with layers of data on storm water, drainage, and soil condition, as well as aircraft traffic data.

10. All pavement attribute data for pavement inventory, distress, condition, roughness and skid resistance will be linked graphically to the proper pavement sections.

11. The GIS must be capable of performing the following spatial operations: (in the absence of specific software, the spatial operators likely to be used should be listed).

12. Determine if the airport requires the software to perform dynamic segmentation. This function is popular in GIS for highways, but may not be necessary for airports unless plans include a number of field inspections (other than distress surveys) for pavement condition index.

13. The airport should specify the number of users, the number of hardware locations, the type of network to connect the computers and the various output devices needed.

Proposed Airport GIS

Airport authorities should develop geographical information systems that allow for multiple users and applications. Many of the GIS now being developed are designed for a single application. Since the FAA monitors and approves most major projects under development, airport fundings is limited. Most of the potential applications of airport GISs will qualify for federal funding, either under the airport improvement program, planning grants or under the voluntary Part 150 program. The ideal solution is to develop the GIS under an application eligible for funding, then tack on additional applications later, as time and resources permit.

A recent survey of GIS use at U. S. Airports found that although only 25% are using GIS, 58% are planning to within 36 months and, while only 25% of the airports using GIS have pavement management applications, 70% plan to(McNerney, 1995).

The major cost of developing a GIS is not the hardware or software required, but the development of the graphic and attribute data. If a GIS is going to be developed for noise mitigation, the airfield pavements must be entered into the graphic data, anyway. If the graphic data is entered in such a way that a pavement management system can be supported by the same GIS with a different attribute database, the cost of developing the applications has been reduced considerably.

An airport large enough to invest in a management system of some kind, probably is large enough to have a GIS. Even small airports are required to prepare master plans, airport layout plans and storm water pollution prevention plans, to name a few. In the long run, it will be more cost effective to computerize these data in CAD drawings. Once CAD drawings are completed, an entry level GIS can be started on a personal computer.

By planning for GIS applications in the airport's data management plan and GIS application that is funded, future applications can be added at lower costs. The ultimate power and usefulness of a GIS is not measured by the ability to perform the intended single application; the real strength is in its ability to analyze quickly a critical problem that was not even known when the system was designed.

Summary and Conclusions

A full-cost approach to airport pavement management should not be limited to agency costs, but include the economic factors of aircraft delays and user costs. It also should provide a mechanism to address environmental costs of aircraft operations on air and water quality and noise. The best way to include these costs into a pavement management system is to have a PMS fully integrated into an airport GIS.

The congressional mandate for an effective airport pavement maintenance management system will be interpreted by the FAA as a minimal requirement that general aviation airports can accomplish without a computer for pavement inventory, inspection, maintenance and record keeping. Traditional PMSs for airports have been built upon the FAA's endorsed MicroPAVER system that was designed to minimize airport pavement maintenance budgets. Although PAVER and MicroPAVER represented major advancements in the 1970's, they are nearly obsolete as far as their usefulness in the management of pavements at air carrier airports. With the technology now available, it would be short-sighted to attempt to minimize cost by building a modern pavement management system at an air carrier airports using only the pavement condition index.

The new focus of airport management is minimizing the cost per enplaned passenger while providing a high level of service. Therefore, modern airport pavement management requires an enhanced pavement management system (EPMS) that captures the full range of cost items related to airport pavement use and that can be modified and calibrated to suit the needs of specific airports. While certain cost items, such as pollutants cannot easily be represented in monetary values, they can be evaluated using a multi-attribute criteria approach.

Using an EPMS with an airport GIS will ensure that the most appropriate pavement construction, maintenance and rehabilitation strategies are selected to satisfy the needs of the airlines, airport users and airport authorities striving for a cost competitive system.

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